Analysis of response time of twisted-nematic liquid-crystal cells with low twist angle

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Abstract

Fast response time is realized by using LTN-LCDs. To calculate the dynamic electro-optical characteristics, Ericksen-Leslie theory is used for the dynamic profile of molecules and order tensor representation is adopted for the free energy calculation.

Introduction

As the application of liquid crystal displays (LCDs) increases, there has been a remarkable interest in designing LCDs with high contrast ratio, wide viewing angle, good gray-scale capability and fast response time. Especially, for the application to moving pictures with full color, it is necessary to realize high speed and good gray-scale capability. In order to obtain good gray-scale capability LTN-LCDs have been introduced by Schadt [1].

In this study, it is revealed that LTN-LCDs shows fast response time as well as good gray-scale capability because the relaxation time of liquid crystal molecules in this middle layer is short due to the small twisting angle. To realize fast response time, we optimized the design and material parameters by using computer simulation.

Calculation of Electro-optical properties

In this paper, we analyzed transmission-response characteristics for the symmetric A structure suggested by Palmer [2,3]. Figure 1 is the symmetric A structure of LTN-LCDs, which operates in normally, white mode.

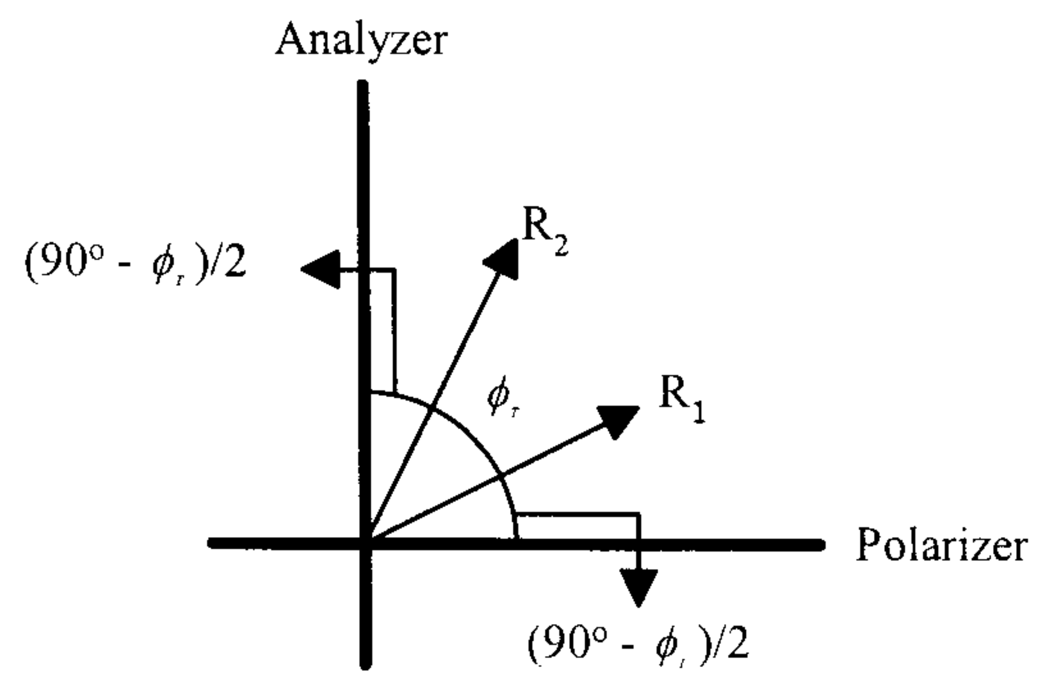

FIG.1. Symmetric A structure of LTN cell; R1 is rubbing direction of lower plate and R2 is rubbing direction of upper plate

To obtain the electro-optical characteristics, we calculate the dynamic deformation profile of liquid crystal molecules by using Ericksen-Leslie theory. Especially, for the calculation of the Gibbs free energy, we adopted the order tensor representation [4]. First, to analyze the effect of twisting angle on the response time, we determined the value of Δ nd for nonselect voltage as a function of twisting angle. The device and material parameters used in simulation are shown in table 1. Figure 2 shows the optimized value of Δ nd for various twisting angles. The applied voltages are taken as 1V for nonselect voltage and 6V of 30msec for select voltage.

Table 1. List of parameters used in the simulation.

Input parameter	Value	
Parallel permittivity	$\varepsilon_{\parallel}$	8.4
Perpendicular permittivity	$\varepsilon_{\perp}$	3.1
Ordinary refractive index	n_{ord}	1.4745
Splay elastic constant	k_{11}	13.9×10^{-12} [N/m]
Twist elastic constant	k_{22}	6.5×10^{-12} [N/m]
Bend elastic constant	k_{33}	18.2×10^{-12} [N/m]
Cell thickness	d	5 μm
Input wavelength	λ	550 μm

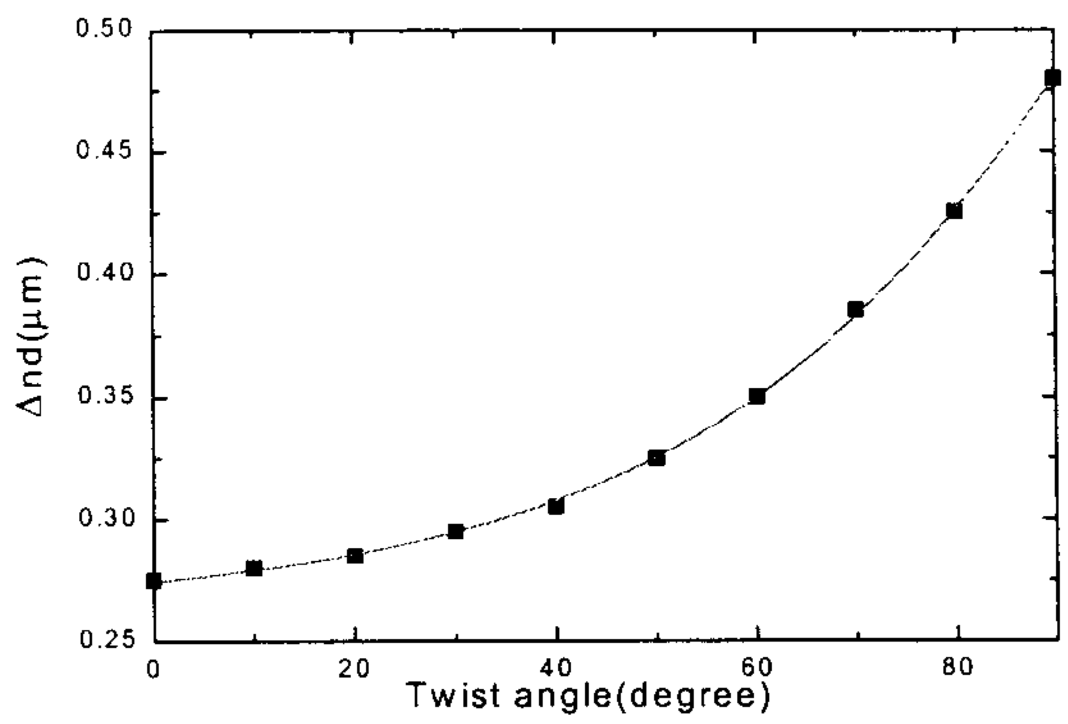

FIG.2. Optimized Δ nd of various twist angle

Results and Discussion

Fig 3 shows the dependency of transmittance on the twisting angles. From the figure, it is revealed that the response time becomes fast with the twisting angle and eventually becomes saturated about 30□ twisting angle. In this study, we determined the twisting angle as 30□ considering the gray-scale capability.

Fig 4 shows the relationship between response time and pretilt angle. The rising rime for select voltage becomes fast according to the pretilt angle. On the contrary, the decay time for the nonselect voltage becomes slow. Therefore, remarkable variations in average response time can be hardly seen for various pretilt angles.

Fig 5 shows the dependency of response time on the k33/k11. It is revealed that the response time decreases with increasing the value of k33/k11. But, as shown in Fig 6, the increase of k33/k11 results in the increase of threshold voltage.

In this study, we determined the value of k33/k11 to be between 1.5 and 2 in order to realize simultaneously low threshold voltage and fast response time.

Conclusion

In this study, we analyzed the effect of twisting angle, pretilt angle and elastic constant on the response characteristics. As a result, we chose 30□ as twisting angle for LTN-LCDs in order to obtain fast response time. We confirmed that there is no clear relationship between pretilt angle and response time. Also, considering the threshold voltage and response time simultaneously, we determine the value of k33/k11 to be between 1.5 and 2.

Acknowledgements

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References

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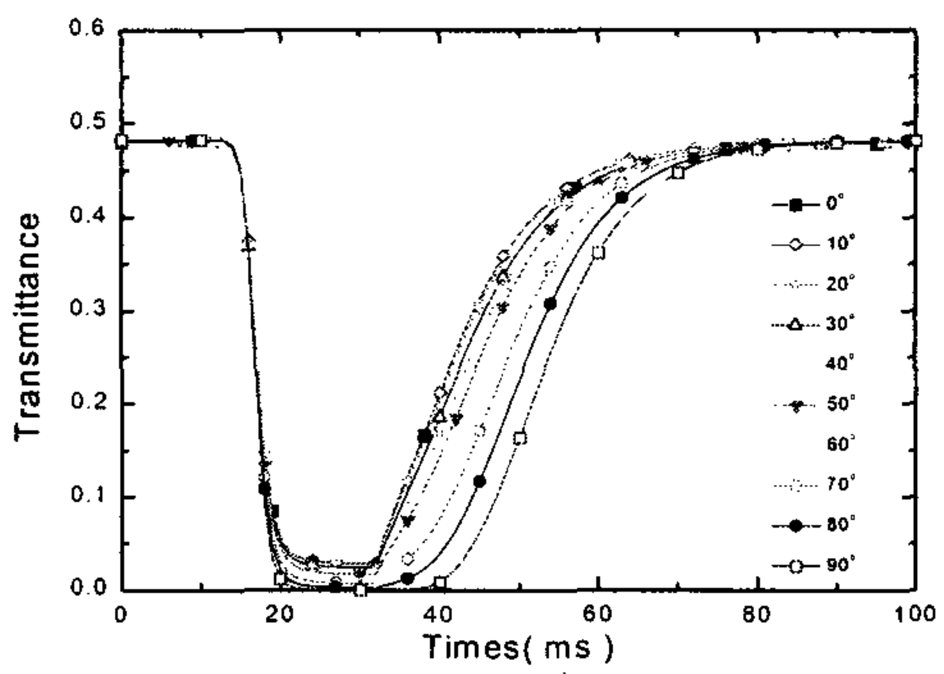

FIG.3. Time dependency of transmission curves for various twist angles at the normally white mode. 6V pulse is applied at 12msec and removed at 32msec.

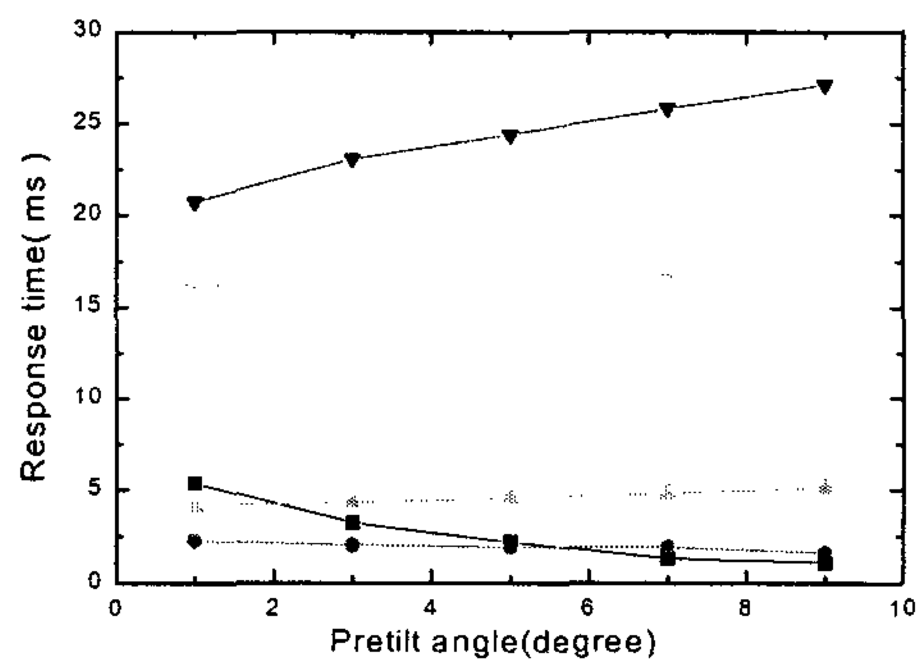

FIG.4. Pretilt angle dependencies of response time. ▼, ◆, ▲, ● and ■ represent τ_r, τ, τ_{dr}, τ_f and τ_{df}, respectively

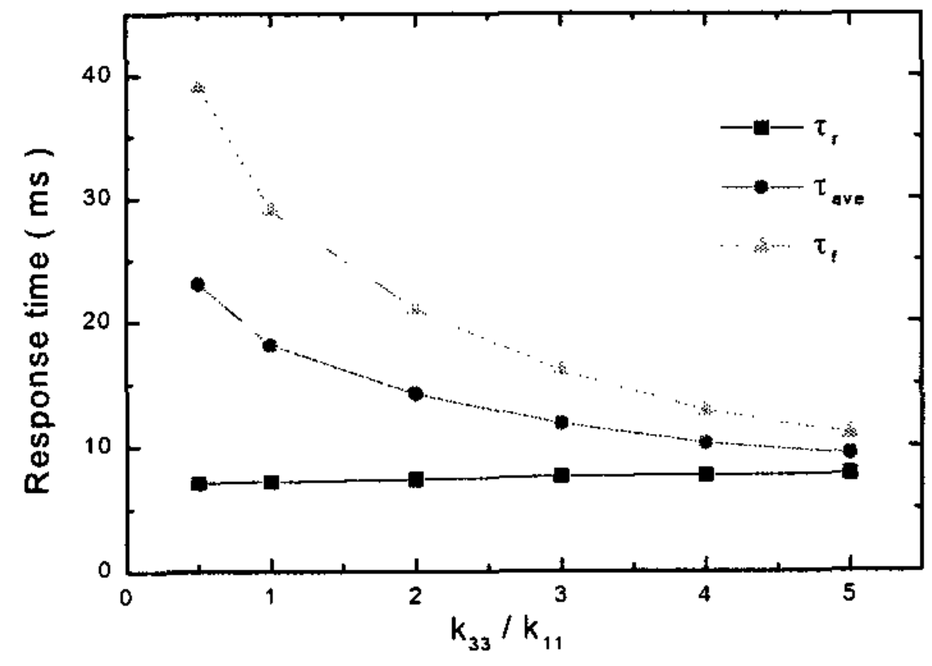

FIG.5. k33 /k11 dependencies of rising and falling time for 30° LTN

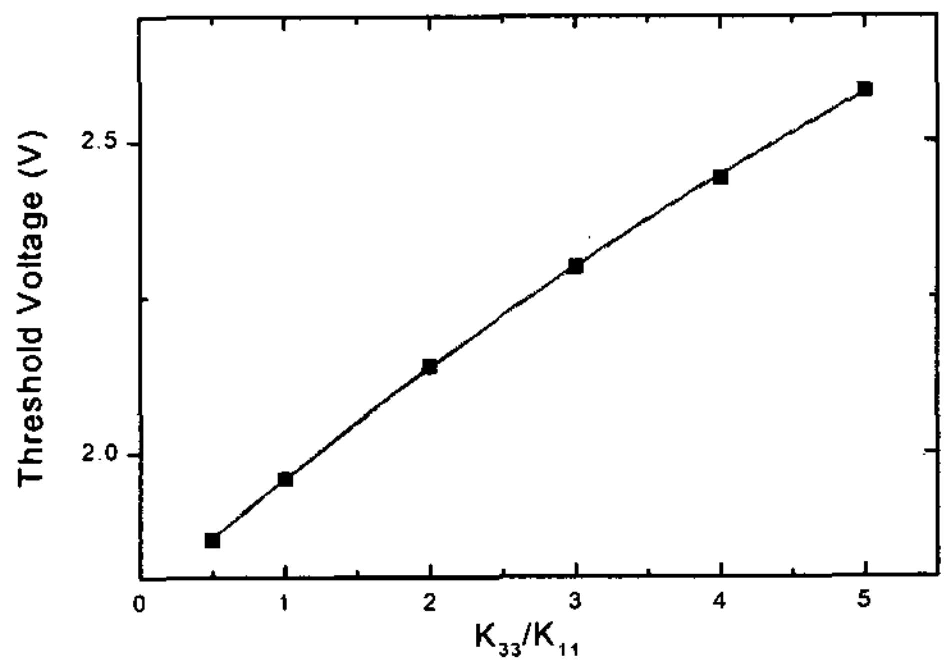

FIG.6. K33 /K11 dependencies of threshold voltage for 30° LTN